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EDI in South Africa: An Assessment of the Costs and Benefits

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Abstract

EDI is a method of exchanging common business documentation between organisations by replacing paper transactions with electronic messages. The use of EDI can eliminate or significantly reduce the problems associated with paper-based transmission systems. EDI can provide substantial benefits: improved efficiency and reduced costs; improved internal operations resulting from a reduction in time delays; better responsiveness to customers; improved channel management; and increased ability to compete both domestically and internationally.

The aim of this research is to assess the degree to which the benefits of EDI are currently being realised in South Africa. In addition, the cost of EDI is addressed, focusing on the various cost elements that must be considered and the factors which impact the level of cost. Ultimately, the cost of implementing EDI on various platforms is estimated.

The research results suggest that the majority of industries surveyed are realising some degree of benefit from EDI. It appears that the mid-range EDI applications are generating the most benefit, while stand-alone PC implementations are not delivering any benefit. The results indicate that the benefits being realised to the greatest extent are the improvement of data integrity, followed by the achievement of closer trading partner relationships. The benefits that are being realised to a lesser degree are the reduction in inventory holdings, facilitation of JIT production, improved supplier responsiveness, decreased mailing costs, reduced forms and stationery expenses, and the optimal utilisation of staff.

Keywords: *Electronic Data Interchange (EDI), EDI benefits, EDI costs, EDI standards, EDIFACT, EDI software, EDI networks, VAN, EDI hardware configurations*
Computing Review Categories: *H.3, H.4.3*

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1 Introduction

The majority of companies today have implemented computer systems to capture and store data, make accurate information available to management and to keep the internal workings of the organisation under control. However, most of these same firms transcribe the information onto paper when it is required by external organisations and then send it either by post or fax. The data arriving on paper then has to be rekeyed into the recipient's computer system [17, 10, 16].

The result is a large amount of paperwork which flows between different organisations in order to purchase, distribute and sell goods and services [16]. This method of data transfer results in numerous problems and inadequacies. The creation, handling and distribution of paper documents is a relatively slow, labour-intensive and error-prone process. More importantly, the transfer of data is subject to delay and uncertainty, as the postal service is often relied upon to deliver the documentation [14].

An alternative method of exchanging information, one which replaces paper transactions with electronic messages, is known as Electronic Data Interchange (EDI) [16]. EDI offers the opportunity for companies to save time and money and increase efficiency through the elimination of paper documents [14]. Research shows that EDI is increasing steadily as a means of conducting business [11]. It is predicted that the rate of growth of EDI is between 50 and 80 percent per annum up to the year 2000 [20].

The use of EDI can eliminate or significantly reduce the problems associated with paper-based systems [17]. EDI eliminates the delays inherent in mailing documentation, thereby enhancing certainty of the information flow [7, 4]. EDI saves time and reduces labour costs as it eliminates the tasks of processing incoming mail and re-entering data [21, 17]. In addition, the opportunity for error is greatly reduced since data is not repetitively rekeyed [6, 21, 1].

At a minimum the benefits of EDI include improved efficiency and reduced costs. However, EDI can have a far more significant impact on a company than just a reduction in costs. When EDI is viewed and used as a new approach to doing business, the benefits from EDI can be substantial [23, 4]. These include improved internal operations resulting from a reduction in time delays [18]; better responsiveness to customers [2]; improved supply-chain management [5] and increased ability to compete, both domestically and internationally [8].

Neither the concept nor the application of EDI are particularly new *per se* [10]. EDI systems are widespread in many parts of the world, especially in the United States and Europe [24]. In addition, the benefits of EDI have been extensively documented and publicised. However, there is little evidence of the extent to which the theoretical benefits of EDI are being realised in South Africa. Furthermore, the issue of the cost of EDI is complex as there are a broad range of possible implementation configurations and numerous factors which impact the level of EDI cost.

In light of the above-mentioned problems, the follow-

ing research questions have been proposed:

1. To what extent are the benefits of EDI being realised in South Africa today?
2. What is the cost of implementing EDI in South Africa today?

Therefore, the aim of this research is to assess the degree to which the benefits of EDI are currently being realised in South Africa, and to identify the various costs that must be considered and the factors which impact the level of cost. Ultimately, the cost of implementing EDI on various platforms will be estimated.

The paper consists of two main sections. The first section comprises a literature review which defines EDI; briefly explains its concept, components, and hardware configurations; and discusses the benefits of EDI, the various cost categories to be considered and the issues related to the measurement of EDI costs and benefits. The second section presents a synopsis of the results of the research.

2 What is EDI?

The definition of EDI as defined by SITPROSA (Simplification Of International Trade Procedures in South Africa) is as follows:

> "EDI is the electronic exchange of machine processable, structured data which has been formatted to agreed standards and transmitted across telecommunications interfaces directly between different applications running on separate computers."

EDI is the technology which moves data electronically, without human interpretation or rekeying, between the sender's application program and the receiver's application program [8]. The data that is transmitted between trading partners is in a standardised format and represents common business correspondence such as purchase orders, invoices, and shipping notices [14].

EDI is a subset of a larger class of systems known as inter-organisational systems (IOS) [3]. What distinguishes EDI from other systems in this category is the fact that data flows directly from one computer system to another, without human intervention in between [1]. In other words, an important aspect of a true EDI system is that data must only be keyed into any computer system once by the owner or source of the data [17].

3 The Components of EDI

Sending or receiving an EDI message requires the following three elements: EDI standards, EDI software, and EDI networks [8].

EDI Standards

Standards are the key to making EDI viable [20]. It is the commonly agreed standard format of business documents between users that distinguishes EDI from other free-format data flow systems [11]. EDI Standards are rules of format and syntax that govern electronic data interchange communications [16]. They are the common language which enable one application to understand the information passed to it from another application [13]. EDI standards may be proprietary, industrial (for example, ODETTE in the automotive industry), national (for example, ANSI.X12 in America) or international (the United Nation's EDIFACT, which stands for EDI For Administration, Commerce and Transportation).

EDI Software

EDI software performs three basic functions of data formatting, data conversion, and message communication [8]. The formatting function is the most important function of EDI software as it translates data from an unstructured company-specific format to an EDI standard format [19]. The conversion function extracts data from the company database and restructures it into a flat file which can be read by the translation software [15]. This conversion process is also known as *mapping* the application to the EDI software. Finally, the communications software controls the transmission and receipt of EDI messages by interfacing with the communications modem to establish the speed and type of transmission.

EDI Networks

There are essentially two ways in which trading partners can be connected: directly (point-to-point) or via a third party network [8].

In a direct EDI network, the computers of the trading partners are linked directly, usually through dial-up modems [18]. A direct system works well when a company is communicating electronically with only a limited number of trading partners. However, as the number of trading partners increases, the difficulty of maintaining open lines for the trading partners, of co-ordinating the timing of transactions, of assuring communications compatibility, and of maintaining communications security also increases [2, 18]. To overcome these problems, many companies trading via EDI communicate with trading partners through a third party network [22].

A third party network serves as an intermediary between trading partners. A third party network performs the same function for electronic documents as a post office does for paper documents [14]. In addition to this fundamental mailbox service, a third party network may also provide value added services such as translation to EDI standard, international connections, connections to other third party networks and training [16, 19]. When additional services such as these are provided, the third party network is known as a Value Added Network or VAN [10].

4 EDI Hardware Configurations

There is no specific hardware requirement in order to perform EDI. As EDI software is available for mainframe computers, mid-range computers and microcomputers, EDI can operate on any of these hardware platforms [9, 8]. The most common hardware and software configurations used

to perform EDI are discussed below.

The first possible configuration is to have all the EDI software reside on the mainframe or mid-range computer and to have that computer perform all EDI functions. This configuration has the advantage of being able to process high volumes of transactions very rapidly. However, mainframe/mid-range EDI software is considerably more expensive than microcomputer software [8].

Alternatively, all EDI software can be housed on a microcomputer (PC), which performs all EDI functions. This configuration is also known as "stand alone" since the EDI activity is distinctly separate from other computer activity within the firm [8]. Stand-alone applications have the advantage of being relatively inexpensive, quick to set up and fairly easy to use. However, stand-alone EDI is not EDI in its truest sense since data received on the PC must be rekeyed before being processed [8].

A third way to configure an EDI system is to use a microcomputer as a front-end-processor to a mainframe. In this configuration, data stored in the mainframe is extracted into a file and transferred to the PC which then performs the EDI functions of translation and transmission. This configuration has the advantage of being less expensive than a mainframe or mid-range application, while providing more speed than a stand-alone application. However, this arrangement is not as inexpensive as the stand-alone configuration, nor is it as fast as a mainframe alone [8].

5 The Benefits of EDI

Although the types of benefits realised from EDI are similar across all usage of EDI, the degree to which the benefits are realised varies significantly from one user to another [8]. Various factors impact the extent to which EDI benefits are achieved, including the hardware platform used, the volume of EDI transactions and the degree to which EDI is integrated with existing applications [8, 19]. The benefits of EDI are both tangible and intangible [2].

EDI reduces the time in the business cycle from order placement to receipt of goods funds. This reduction in time can lead to additional benefits of reduced inventory, Just-In-Time (JIT) production, Quick Response (QR) retail, increased cash flow and lower operating costs. EDI also eliminates much of the rekeying required under a manual system. This leads to fewer errors and, therefore, less manual reconciliation of different documents; potential personnel reductions and lower administration costs. These benefits are largely of a tangible nature.

Furthermore, because EDI reduces delays and provides more accurate information, companies can be more responsive to customers' needs. This may lead to better customer service and increased sales, ultimately contributing to enhanced profitability and competitiveness. In addition, the reduction in administrative activity releases personnel to perform more effective and productive tasks. These benefits represent intangible benefits.

Although tangible benefits such as cost reduction are significant, the most important benefits of EDI are the intangible benefits which ultimately result in strategic advantage for the organisation [12, 14, 2, 3, 8]. These advantages include improved internal operations, increased customer responsiveness, improved trading partner relationships and supply-chain management, and increased ability to compete internationally. Another important "benefit" is the avoidance of what might happen to an organisation if EDI is not implemented. Although EDI cannot deliver long-term competitive advantage, failure to use it can deliver lasting competitive disadvantage [13].

6 The Costs of EDI

The costs of implementing EDI vary significantly depending upon the hardware platform used and the volume of EDI transactions transmitted [8]. The costs of implementing EDI are both direct and indirect. Direct EDI costs may be categorised into investigation and research costs, hardware, software, communications, training and maintenance costs.

Investigation and Research Costs

A substantial cost may be incurred in the performance of an initial investigation into EDI. This investigation focuses on aspects such as the technology of EDI, the business implications of EDI, the re-engineering of current business processes, the feasibility of EDI and the benefits and costs of EDI to the organisation. This investigation represents a once-off fixed cost incurred early in the EDI effort.

Hardware Costs

EDI hardware costs include the purchase of any computer equipment necessary to perform EDI. While most organisations are likely to already have all the necessary equipment, some organisations may need to purchase a microcomputer and/or a modem for communications purposes.

Software Costs

There are essentially two software costs: the cost of the EDI software and the cost of modifying existing applications in order to integrate the EDI software with business systems.

EDI software may be purchased from software vendors or developed in-house. Usually, the software is purchased, as developing customised software is considerably more expensive and because a wide range of EDI software is available on the market, particularly for microcomputer and front-end applications. In general, EDI software for a mainframe is significantly more expensive than for a microcomputer [8].

Another factor that influences software costs is the degree to which EDI is integrated with internal applications. If EDI is implemented as a stand-alone function, no additional software, beyond the translation software, is needed. However, if the EDI system is highly integrated with internal application systems, additional software development and modification is necessary.

Communications Costs

Costs are incurred in the actual transmission of electronic communications between trading partners. If trading partners are linked directly, the communications costs will vary depending upon whether dedicated communication lines or public communication lines are used. Where third party networks or VANs are used, both once-off and on-going costs are incurred. The on-going costs are of a variable nature and will therefore depend on the volume of EDI.

Training Costs

Virtually every implementation of EDI requires some form of training for both company and trading partner personnel. Training may be provided in-house as well as by vendors or VANs. The most significant amount of training is incurred up-front, with a limited level of on-going training required to keep personnel abreast of changes in standards and technology [8].

Maintenance Costs

On-going maintenance of EDI software is necessary to ensure that the software can handle updated versions of EDI standards, as well as to incorporate new messages. Furthermore, the addition or modification of a message may require operational systems that function around that message to be adapted. Software maintenance costs vary depending on the computer platform and EDI software used.

In addition to the above-mentioned direct costs of EDI, indirect costs may also be incurred. Indirect costs include the following:

- EDI has the potential to bring about fundamental change in the way business is done. Ready acceptance of such change is rare [2].
- EDI introduces a risk to the integrity and confidentiality of transmitted information [7]. Sensitive or competitive information may be divulged (either accidentally or deliberately) on networks or in the mailbox storage system [24]. In addition, EDI messages may be corrupted or lost while being transmitted [12]. As a result, security policies and procedures must be put into place to ensure authorised transaction processing and the prevention and detection of data manipulation or loss [2].
- The removal of paper documents and the traditional audit trail in an EDI system makes the tracing of transactions from their source to the records in the books of account, or *vice versa*, more difficult [12].
- The legal structure and rules are built to serve a paper-based trade system [13]. As many of the existing terms and conditions of trade include references to paper and postal systems, it is necessary for trading partners to negotiate and enter into a well-structured interchange agreement [7, 13]
- The elimination of human processing of documents changes the organisation's internal control environment, necessitating the modification of existing internal controls [18].
- EDI poses a risk to the continuity of business [24]. Procedures need to be developed and implemented to enable the organisation to continue transacting should the system by unavailable for an extended period [12].

7 Measuring EDI Costs and Benefits

There are two important characteristics of EDI costs and benefits. Firstly, costs are incurred relatively early in the EDI effort while savings are realised later [8]. Secondly, the costs of implementing EDI are usually readily identifiable and quantifiable, while the benefits associated with EDI, although typically far outweighing the costs, are not always as clearly visible and measurable [22, 12]

EDI typically does not deliver quick payback [22]. A large portion of EDI costs tend to be fixed, up-front-costs which are incurred before any EDI can actually be performed. The benefits tend to be long-term and only begin to be apparent at a later stage in the EDI effort. The benefits are most limited during the time when the costs tend to be the highest [8].

Although an organisation may incur indirect costs as a result of implementing EDI, the majority of the costs incurred are hard figures which can be easily quantified. Benefits, on the other hand, are predominately soft or intangible, and subsequently difficult to measure. Estimating the amount of inventory that will be saved, the amount of paperwork that will be reduced, or the number of personnel that will be released is often subjective, and although difficult, it is not impossible. However, measuring the effect to the bottom-line of improved customer service, enhanced trading partner relationships, increased ability to compete internationally, improved information accuracy, and more efficient internal operations, is virtually impossible [8].

As the majority of costs tend to be hard figures, which are relatively easily quantified, the research attempts to estimate the monetary value of these costs. The research does not attempt to measure the indirect costs of EDI. Furthermore, this research does not aim to quantify EDI benefits for three reasons. Firstly, EDI benefits are largely of an intangible nature. Secondly, the technology of EDI is relatively immature in South Africa. In general, as technology matures, so the benefits of that technology become more easily quantifiable [20]. Thirdly, quantifying the benefits, even the more tangible benefits, is highly subject to a particular organisation as it depends on, *inter alia*, the cost of performing the manual processes prior to EDI.

8 Research Methodology

Benefits Assessment

There is a wide range of benefits associated with EDI and because of this extreme number of benefit issues, it was decided that a relatively large number of organisations should be surveyed. For this reason, it was concluded that the best way to conduct this aspect of the research was by means of a questionnaire.

Questionnaire A, a copy of which is appended to this article, was designed to measure the extent to which the

benefits of EDI are being realised. One hundred questionnaires were mailed to firms that have implemented EDI. Forty questionnaires were returned, of which two had not been completed. The remaining 38 questionnaires were used for data analysis. However, 9 of the 38 companies were either investigating EDI or were in the internal testing or pilot stages of implementation. For this reason, they were unable to comment on the realisation of benefits, and Part C of the questionnaire was omitted. This resulted in only 29 questionnaires being available for benefits analysis.

Cost Assessment

Due to the complex nature of EDI costs and the considerable time and effort required by an organisation to compile such information, it was decided that a mailed questionnaire would be inadequate for this aspect of the research. Therefore, this research was conducted by means of detailed interviews with six organisations. These organisations comprised two VANs, two EDI software vendors and two organisations that have implemented EDI.

Questionnaire B, also appended, was designed as an interview guide which, if possible, was completed by the interviewee.

9 Findings and Results of Research

Analysis of Response By Industry

Part A of Questionnaire A identifies the industry in which the respondent's organisation operates. The pie chart in Figure 1 shows the proportion of respondents in each industry classification. The "Other" category comprises the Telecommunications, Financial Services, Transport and Export industries. Manufacturing, Retail and Mining industries were the best represented, containing 52%, 16% and 11% of the questionnaire respondents respectively.

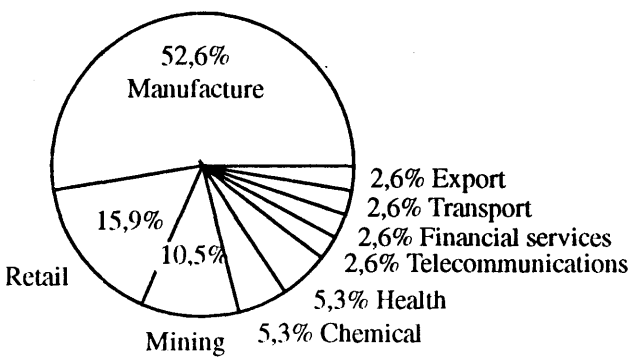

Figure 1. Analysis of Respondents by Industry

Analysis of General EDI Details

Part B of Questionnaire A attempted to extract general details regarding the implementation of EDI in the respondent's organisation. The data is analysed as follows.

Breakdown by EDI Implementation Stage

Figure 2 shows the proportion of respondents in each EDI implementation stage. The EDI status of the majority of questionnaire respondents is *live* (63%). The *pilot* stage is represented by 24% of the respondents, while *investigation* and *internal testing* are being performed by 8% and 5% of the respondents respectively.

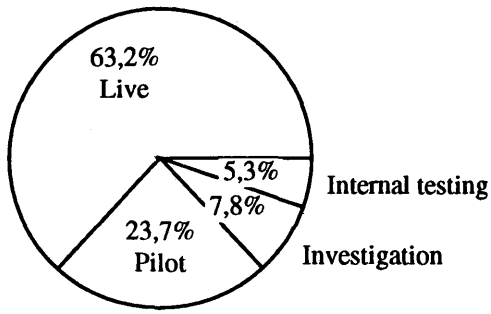

Figure 2. Analysis of Respondents by EDI Implementation Stage

Breakdown by Trading Partner Type

Trading partner type refers to whether an organisation is an initiator and industry leader of EDI (known as the hub company) or a follower of that hub company. A follower usually implements EDI upon request, or even demand, by the hub. Figure 3 illustrates the number and percentage of respondents per trading partner type.

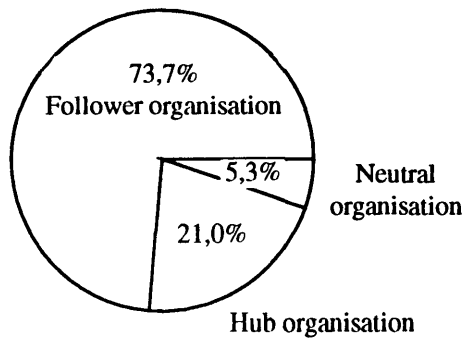

Figure 3. Analysis of Respondents by Trading Partner Type

Of the 38 questionnaire respondents, 21% classified themselves as hub companies, which had insisted that their trading partners comply with their request for EDI. The majority, that is 74% of the respondents, classified themselves as followers. Two of the respondents (5%) stated that they were neither a leader nor a follower, and that there existed a mutual commitment towards EDI in their industry.

Breakdown by Platform

The pie chart in Figure 4 shows the proportion of respondents that have implemented EDI on each of the major platform configurations. The majority of respondents (56%) have implemented EDI on a stand-alone PC. A PC front-end to a mainframe computer is the next most widely used

configuration (18%). Mid-range computers and PC front-end/mid-range computers are used equally by respondents. A mainframe computer on its own is not used by any of the respondent organisations.

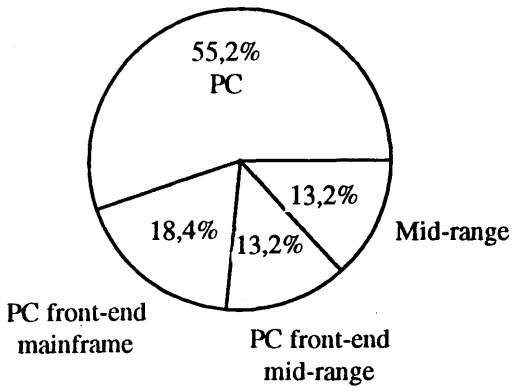

Figure 4. Analysis of Respondents by Platform on which EDI is Implemented

Reasons for implementing EDI

Table 1 details the reasons cited by respondents for implementing EDI and their corresponding frequencies. This question (Part B, Question 5) was presented in open-ended form, and responses were grouped to represent, as closely as possible, the words of the respondents. Many respondents omitted to answer it, while others furnished more than one reason for implementing EDI. For this reason, the results of the analysis of this question's data are not completely representative. It does serve, however, to highlight the major concerns of organisations when implementing EDI.

Table 1. Reasons Given for Implementing EDI

Reasons for implementing EDI	Nr	%
1. Business survival	14	23,7
2. Reduce errors	9	15,2
3. Improve customer satisfaction	8	13,5
4. Reduce costs	7	11,9
5. Reduce inventory holdings	6	10,2
6. Reduce payment delays	4	6,8
7. Improve trading partner relations	3	5,1
8. Achieve competitive advantage	3	5,1
9. Improve data integrity	3	5,1
10. Improve internal operations	2	3,4
	59	100%

Of particular interest, is the most frequently cited reason for implementing EDI, that is, for business survival. Many of these respondents stated that they had implemented EDI in order to comply with a major customer's request. They either invested in EDI or faced the loss of important business. Others stated that EDI was set to become an accepted way of doing business in the future, and that at some stage, would be essential for business survival. These results suggest that the use of EDI in certain South African industries has grown to the level where it is considered essential for conducting business.

Other commonly cited reasons for implementing EDI include improvement of customer satisfaction, decrease or elimination of errors and reduction in costs.

Analysis of Message Types Transmitted

Table 2 analyses the number of organisations that transmit each type of electronic message. The most frequently transmitted message is an order, which is transmitted by 86,8% of the organisations surveyed. Invoices (28,9%), payments (21,1%), shipping confirmations (21,1%), pricing confirmations (13,2%), transaction acknowledgements (7,9%), and tenders, quotes and product information (7,9%) are also frequently transmitted messages.

Analysis of Benefits Realised

Part C of Questionnaire A attempted to measure the extent to which the benefits of EDI have been realised by means of twelve four-point scales, each representing an EDI benefit. As stated above, only 29 of the 38 respondents were able to complete this section of the questionnaire.

The results of Part C are presented in Table 3, which contains, for each questionnaire, the response for each of the twelve benefits, represented by a number between 1 and 4. A score of 1 suggests that the benefit has not been realised at all, while a score of 4 means that the benefit has been extensively realised. The average benefit realised for each respondent is given, as well as the average level of realisation for each benefit. An average score above the mean of 2,5 suggests that the benefit is being realised to some extent, while an average score below 2,5 implies that the benefit is not being realised.

The Average Benefit Realised Per Industry

Table 4 details the average benefits realised per industry. The Chemical, Transport, Financial Services and Telecommunications industries were each represented by only one respondent, and were therefore combined into the "Other" category.

Table 4. Analysis of Benefits Realised per Industry

Industry	Number	Avg benefit
Other	4	3,49
Health	2	3,36
Retail	6	2,58
Mining	3	2,40
Manufacture	14	2,16
Overall average		2,798
	29	

The average benefit ranges from 2,16 for the manufacture industry, to 3,49 for the "Other" category which comprises the four industries mentioned above. With the exception of the manufacturing industry, the industry averages are above 2,5 suggesting that the benefits of EDI are being realised to a certain extent. The overall average for all organisations is 2,798. These results should be interpreted with caution due to the uneven distribution of respondents between industry categories.

Table 2. Analysis of Message Types Transmitted

Message type		Frequency of transmission	% of companies transmitting message
1.	Order	33	86,8%
2.	Invoice	11	28,9%
3.	Payment	8	21,1%
4.	Shipping confirmation	8	21,1%
5.	Pricing confirmation	5	13,2%
6.	Transaction acknowledgement	3	7,9%
7.	Tenders, quotes & product info.	3	7,9%
8.	Technical specification	2	5,3%
9.	Medical aid claim and response	2	5,3%
10.	Goods received confirmation	1	2,6%
11.	Contract confirmation	1	2,6%
12.	Statement	1	2,6%
13.	Stock availability advice	1	2,6%
		79	

Table 3.

No.	Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Avg
1	2	1	3	4	3	3	1	4	2	1	3	1	2.33
2			3		4	4	4	4	4	3	4	3	3.67
3	1	2	1	3	4	1	1	1	1	1	1	1	1.50
4	1	1	1	1	4	3	1	3	1	2	1	2	1.75
5	1	1	4	1	3	2	1	1	1	1	2	1	1.58
6	1	1	4	4	4	4	4	1	1	1	1	1	2.25
7			3	4	3	4	4	3	3	3	3	3	3.30
8	1	1	4		4	4	4	4	1	1	4	4	2.91
9	1	1	1	1	1	4	3	4	1	1	1	1	1.67
10	1	3	3	3	2	3	1	1	1	1	1	1	1.75
11	1	2	3	3	2	4		3	1	1	4	3	2.45
12		4	4		4	4	4	4	4			4	4.00
13		4	3		4	4	4	4	3	4	4	3	3.70
14	1		3	3	2	4	1	4	4	1	1	2	2.36
15	3	3	3	3	3	4	3	3	3	4	3	4	3.25
16	2	1	3		3	4	1	3	1	1	4	2	2.27
17						3		3			3	3	3.00
18	2	2	3	1	4	4	2	2	1	1	4	1	2.25
19	1	1	1	1	1	1	1	1	1	1	1	1	1.00
20	1	1	4	1	3	4	3	3	1	2	1	3	2.25
21	4	4	4	3	4	4	4	4	4	4	4	4	3.92
22	1	2	4	1	2	3	3	3	1	1	3	3	2.25
23	1				2								1.50
24			3	3	3	3	3	3	2	2	3	3	2.80
25	3	3	4	3	3	4	3	4	4	4	4	4	3.58
26			3		3	3	3	3			3		3.00
27		3	3	1	3	4	3	3	3	2	2		2.70
28	3	3	4		3	3	3	3	3	2	2	2	2.82
29	1	1	1	2	3	3	3	3	1	1	1	1	1.75
Avg	1.57	2.05	2.96	2.30	3.00	3.39	2.62	2.93	2.04	1.84	2.52	2.35	

The Average Benefit Per Platform

Table 5 details the average benefits realised per EDI platform category. The mainframe category has been omitted

Table 5. Analysis of Benefits Realised per Platform

EDI platform	Number	Avg benefit
Mid-range	2	3,80
PC front-end	12	2,66
PC	15	2,27
	29	

since it contains no respondents. In addition, data for both PC/mid-range and PC/mainframe front-end configurations have been consolidated into one category "PC front-end".

The average benefit is 2,27 for a stand-alone PC implementation, 2,66 for a PC front-end implementation, and 3,8 for a mid-range implementation. It would appear, therefore, that the highest degree of benefits are being realised in organisations that have a mid-range EDI configuration and that the benefits are being realised to a lesser degree on stand-alone PC configurations. Once again, however, these results should be interpreted with caution due to the uneven distribution of respondents between platform categories.

The Average Benefit Realised Per Benefit Category

Table 6 details the extent to which each benefit of EDI has been realised by respondent organisations. The results suggest that the benefits being realised to the greatest extent are the improvement of data integrity, followed by the achievement of closer trading partner relationships. The benefits which have an average score of less than 2,5 – thereby suggesting that they are not being realised – are the reduction in inventory holdings, facilitation of JIT ordering, improved supplier responsiveness, decreased mailing costs, reduced forms and stationery expenses, and the optimal utilisation of staff.

A possible reason for the poor realisation of EDI benefits is that many organisations are still running paper-based systems in conjunction with EDI systems in order to accommodate those trading partners that have not yet implemented EDI. With time, more and more trading partners will be connected electronically to an organisation, reducing the extent of manual, paper-based processing and transmitting of transaction documentation, and consequently, increasing the degree to which the benefits of EDI are realised.

The Success Rating of EDI

Part D of Questionnaire A contained a four-point scale which attempted to assess the success of the EDI implementation as perceived by the respondent. A response of 1 suggests that the implementation of EDI was a complete failure, while a response of 4 indicates that the implementation of EDI was highly successful.

The Average Success Rating Per Industry

Figure 5 illustrates the average success rating of EDI per industry in the form of a bar graph. The category "Other",

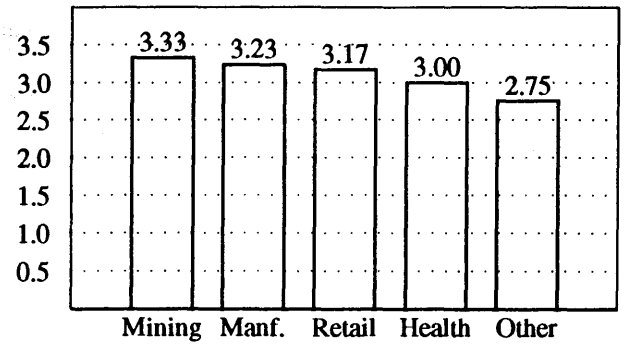

Figure 5. Average Success Rating per Industry

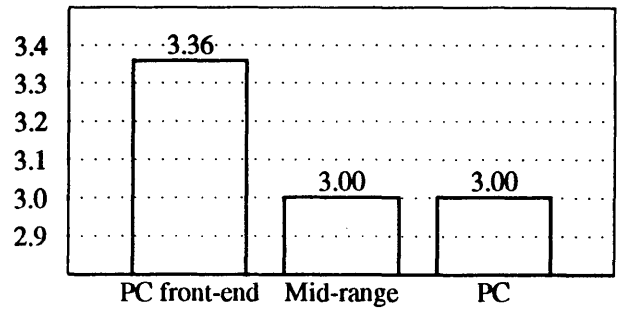

Figure 6. Average Success Rating per Platform

comprises data of four industries, namely Chemical, Transport, Financial Services and Telecommunications.

The average success rating ranges from 2,75 for the four industries in the "Other" category, to 3,33 for the mining industry. The average for each industry surveyed is weighted slightly towards the positive side, indicating that the majority of respondents perceive EDI to be operating successfully in their organisations. The overall average success rating for all organisations is 3,096. These results should be interpreted with caution due to the uneven distribution of respondents between industry categories.

The Average Success Rating Per Platform

Figure 6 illustrates the average success rating per EDI platform category. Once again, the mainframe computer category has been omitted and data for PC/mid-range and PC/mainframe front-end configurations have been consolidated into the category "PC front-end".

The average success rating is 3,36 for a PC front-end implementation, 3,00 for a stand-alone PC implementation, and 3,00 for a mid-range implementation. It would therefore appear that the highest degree of success is associated with PC front-end EDI configurations. Once again, however, these results should be interpreted with caution due to the uneven distribution of respondents between platform categories.

Analysis of Costs

The issue of estimating the costs of implementing and performing EDI is a complex one. This is a result of the many hardware, software, and transmission options available and the various factors which determine the level of cost. Despite these difficulties, the following section attempts to estimate a range for each cost element and for each hardware platform. The implementation of EDI on

Table 6. Analysis of Benefits Realised per Benefit Category

Benefit category		Avg benefit
1.	Inventory holdings reduced	1,57
2.	JIT ordering enabled	2,05
3.	Customer satisfaction increased	2,96
4.	Supplier responsiveness improved	2,30
5.	Closer trading partner relations	3,00
6.	Data integrity improved	3,39
7.	Payment delays avoided	2,62
8.	Clerical errors reduced	2,93
9.	Mailing costs decreased	2,04
10.	Forms & stationery expenses reduced	1,84
11.	More accurate & timeous info.	2,52
12.	Staff more optimally utilised	2,35
	Overall average	2,46

a mainframe alone, that is without a PC front-end, is uncommon in South Africa. For this reason, the information available for a mainframe implementation is not comprehensive. The range of figures for each cost component is contained in Table 7.

Initial Costs

The initial cost incurred to investigate the technical and business issues of EDI is independent of the platform chosen for implementation. This activity usually requires numerous hours of top management's time and frequently an external consultant is hired. Estimates range from approximately R20000 to R250000 for consulting fees, and from between three and one hundred hours of management's time.

Other initial costs include legal fees incurred in drawing up the contracts between trading partners and marketing expenses in order to gain trading partner involvement. Legal fees are estimated at R3000, but will depend on the number of trading partners involved. The cost of marketing varies depending on each organisation, and will be high in hub companies, and low, possibly non-existent, in other companies. For this reason, it is difficult to estimate marketing costs.

Hardware Costs

In most cases, organisations already possess computer equipment on which their internal applications run. Therefore, no additional hardware cost is incurred. However, existing hardware may have to be updated to perform EDI.

Mainframe Implementation If the mainframe approach is selected, the hardware is already available and no hardware costs will be incurred.

Mid-range Implementation If the stand-alone mid-range approach is chosen, the hardware is generally already available and no hardware costs will be incurred (mid-range computers vary in price from between R70 000 and R700 000). In certain circumstances, existing mid-range hardware may need to be updated. One organisation interviewed estimated the cost of upgrading their mid-range computer at R200 000.

Stand-alone PC and PC Front-end Implementations The majority of organisations implement EDI on either a stand-alone PC or a PC front-end. In both cases, a powerful PC and necessary peripherals will have to be acquired if not already available which will cost in the region of R6000 to R10000. Upgrading an existing PC may cost up to R2000.

Communications Equipment Costs

A modem is required in order to transmit data via dial-up lines. This costs in the range of R1000 to R4000, depending on the baud rate required. If the front-end processor of a mid-range or mainframe computer contains communications functionality, the purchase of a modem is unnecessary.

Alternatively, if the X25 network is chosen, special equipment must be purchased costing approximately R12000 for a PC, and between R20000 and R30000 for mid-range. No information was obtained regarding the X25 network costs for mainframes.

EDI Software Costs

EDI software consists of translation software, mapping software and communications software. In addition, connection to most VANs necessitates the purchase of connection software. The EDI software figures estimated below include the costs of all the above-mentioned components.

EDI software for a PC ranges between R10000 and R22000 in cost. Mid-range software is estimated to be between R55000 and R500000. No information was obtained regarding the cost of mainframe EDI software.

Application Modification Costs

This cost is very difficult to estimate because it is different for every organisation. Modification costs depend on the organisation's internal applications, the degree of integration required between the EDI software and internal applications, and the number of EDI messages to be integrated.

One organisation interviewed, stated that the modification of their internal systems had taken three to four days per message. An interview with a software vendor, revealed that the application integration cost is R30000 per mes-

Table 7. The Range of Costs for each Quantifiable EDI Cost Component

Cost category	PC	Mid-range	Mainframe
1. Hardware Requirements			
Upgrade Existing	R0–R2 000	n/a	n/a
Purchase New	R6 000–R10 000	n/a	n/a
2. Communication Equipment			
Dial-up Lines: Modem	R1 000–R4 000	R0–R4 000	R0–R4 000
X25 Network: Equipment	±R12 000	R20 000–R30 000	no data available
3. EDI Software	R10 000–R22 000	R55 000–R500 000	no data available
4. Training	R1 000–R4 000	R4 000–R8 000	R5 000–R10 000
5. EDI Software Maintenance (per annum)	R500–R4 300	R7 500–R12 000	no data available
6. VAN Costs			
Monthly transmission costs	R500–R2 000	±R1 000	±R1 500

sage. This cost applies to all platforms. However, a new EDI product recently released by them, eliminates application integration (integration between the application and the EDI software) completely. The remaining systems integration (integration between various internal applications) cost is R12000 per message. This product is available on mid-range computers only.

Registration Costs

Value Added Networks may charge a small registration fee. Telkom SA charges R14,24 to register an X.400 mailbox.

Training Costs

The cost of EDI training ranges between R1000 and R4000 for a PC implementation, R4000 and R8000 for a mid-range implementation, and R5000 and R10000 for a mainframe implementation.

EDI Software Maintenance Costs

EDI software purchased from a software vendor is usually maintained by them at an annual charge (quoted as a percentage (10% to 15%) of the EDI software cost). Maintenance cost estimates for a PC implementation range between R500 and R4300 per annum. Estimates for a mid-range implementation range between R7500 and R12000. No information was obtained for mainframe implementations.

Monthly Transmission Costs

The cost of transmission varies between organisations depending on the communications medium used, the VAN used, and the volume of messages transmitted. An estimated monthly VAN charge is between R500 and R2000 for a PC, R1000 for a mid-range computer and R1500 for mainframe computer. The monthly cost structures for three South African VANs are shown in Table 8.

10 Conclusion

The research set out to answer the research questions posed at the outset of this paper. In the opinion of the author, this objective has been achieved. However, the benefit-realisation results should be interpreted with caution due to the relatively small sample of organisations and the uneven distribution of respondents between industry categories and hardware platform categories.

The first objective was to measure the extent to which the benefits of EDI are currently being realised in South Africa. The research results suggest that, with the exception of the manufacturing industry, all industries surveyed are realising some degree of benefit from EDI. Furthermore, the results suggest that mid-range EDI applications are generating the most benefit, while stand-alone PC implementations are not delivering any benefit. It appears that the benefits being realised to the greatest extent are the improvement of data integrity, followed by the achievement of closer trading partner relationships. The benefits that are being realised to a lesser degree are the reduction in inventory holdings, facilitation of JIT ordering, improved supplier responsiveness, decreased mailing costs, reduced forms and stationery expenses, and the optimal utilisation of staff.

The second objective was to measure the cost of implementing EDI on each hardware platform. It was possible to estimate costs that are not influenced to a large degree by company-specific factors. The costs which depend largely on the specific organisation and on the volume of EDI effected, were difficult to estimate accurately. In addition, due to the lack of use of mainframe for EDI implementation in South Africa, the cost estimates for this platform are not comprehensive. The factors which impact the level of costs incurred were identified.

This research may be extended by identifying the variables which affect the degree to which EDI benefits are realised. It is expected that a relationship exists between the benefit achieved and the number of years trading with EDI, the number of EDI trading partners, the number of different messages, the number of daily EDI transactions, and the percentage of all transactions that are effected by means of EDI. In addition, further research may focus on the distinction between initially estimated costs and benefits and those actually realised after implementation.

Table 8. The Monthly Cost Structures for Three South African VANs

Charge	Telkom X.400 (1993)	"VAN A" (1992 figures)	"VAN B" (1992 figures)
Subscription			R100 per month
Transmission	The first 2048 characters cost R0,31 to transmit. Thereafter, the charge is R0,03 per 2048 characters.	Charges based on complex formula, which depends on volumes sent per transmission. A few large transmissions per month cost less than many small transmissions.	Charges based on reducing rate. The higher the volume transmitted, the lower the charge. The first MByte costs R203, the next 4MBytes cost R120/MByte, and thereafter, the cost is R100 per MByte. A handling charge of R0,20 per transaction is levied after the first 25 transmissions of the month.
	The charge for 1 MByte of data is approximately R15.	The charge for 1MByte of data varies between R550 and R2 400.	The charge for 1 MByte of data is approximately R200.
Connection to mailbox	R0,16 per minute		
Storage charge	R0,021 per 10 KBytes for every 24 hours a message is left in the mailbox after being "read".	Storage up to 48 hours is free of charge.	Storage up to 120 hours is free of charge.

References

1. R E Barr. 'Are EDI and EFT in your tax filing future?'. *Journal of Systems Management*, **42**(4):32–35, (April 1991).
2. A J Barthis. Electronic data interchange: Planning and implementation. MBA thesis, University of the Witwatersrand, Johannesburg, 1991.
3. R I Benjamin, D W de Long, and M S Scott Morton. 'Electronic data interchange: How much competitive advantage?'. *The Best of Long Range Planning No. 4*, (1990).
4. S Brownlee. 'EDI and integration'. In *EDI'93 Conference*, Johannesburg, S.A., (1993).
5. S Carpenter. 'Electronic data interchange and supply chain management'. In *EDI'93 Conference*, Johannesburg, S.A., (1993).
6. B E Dearing. 'EDI in manufacturing'. In *EDI'93 Conference*, Johannesburg, S.A., (1993).
7. G Duff. 'EDI: Risks, security and solutions'. In *EDI'93 Conference*, Johannesburg, S.A., (1993).
8. M A Emmelhainz. *Electronic Data Interchange - A Total Management Guide*. Van Nostrand Reinhold, New York, 1990.
9. S Fisher. 'Moving data using EDI'. *Byte*, **16**(4):162–163, (April 1991).
10. A A Gundelfinger. Electronic data interchange in international trade. MBA thesis, University of the Witwatersrand, Johannesburg, 1989.
11. J V Hansen and N C Hill. 'Control and audit of electronic data interchange'. *MIS Quarterly*, **13**(4):403–413, (December 1989).
12. A Hari. 'Electronic data interchange: Procedures reengineering'. In *EDI'93 Conference*, Johannesburg, S.A., (1993).
13. D Jackson. *Electronic Data Interchange and the Supply Chain*. Digital Equipment Company, 1991.
14. J Johnston. 'EDI implementation at PPG industries'. *Journal of Systems Management*, **43**(2):32–34, (February 1992).
15. F G Knowles. 'EDI software checklist'. In *EDI'93 Conference*, Johannesburg, S.A., (1993).
16. J McGee and B Konsynski. 'A note on electronic data interchange'. Technical report, Harvard Business School, (July 1989).
17. F Metzgen. *Killing The Paper Dragon*. Heinemann Newnes, Oxford, 1990.
18. D M Noris and E Waples. 'Control of electronic data interchange systems'. *Journal of Systems Management*, **40**(3):21–25, (March 1989).
19. R A Payne. 'EDI implementation: A case study'. *Journal of Systems Management*, **40**(3):14–20, (March 1989).
20. D S Remenyi. *Strategic Information Systems - Development, Implementation, Case studies*. NCC Blackwell, Manchester, 1990.
21. B Ross. 'The EDI initiative in the automotive industry of SA'. In *EDI'93 Conference*, Johannesburg, S.A., (1993).
22. M van den Berg. 'An environment for EDI success'. In *EDI'93 Conference*, Johannesburg, S.A., (1993).
23. R Walker. 'EDI in a worldwide context'. In *EDI'93 Conference*, Johannesburg, S.A., (1993).
24. J Williams. 'Beware the march of EDI'. *Accountants Journal*, pp. 20–25, (December 1990).

Questionnaire A Benefit Analysis

The following questionnaire[1] has been designed to examine the extent to which the benefits of electronic data interchange (EDI) are being realised in South Africa.

The questionnaire has been divided into four parts. Part A relates to information about your organisation. Part B examines the details of the implementation of EDI in the organisation. Part C assesses the degree to which the benefits of EDI have been realised. Finally, in Part D, I would like you to rate the overall success of EDI in your firm, and would welcome any further comments that you would like to make.

Part C of the questionnaire uses a four point scale: 1 = Not realised, . . . 4 = Extensively realised

For each question please tick the appropriate block that corresponds to your opinion of the degree to which the particular benefit has been realised. Please do not tick between the numbers.

For example, your firm's inventory holdings may not have decreased as a result of implementing EDI, and therefore your rating for the first question of Part C will be 1 (Not realised).

If you feel that the degree to which the benefit has been realised is on the good side of average, your rating for the same question will be 3.

Please ensure that all questions are answered by ticking one and only one response.

The questionnaire should not take more than 15–20 minutes to complete. All information supplied by respondents will be treated with the utmost confidence.

Thank you very much for your assistance in this research. Please return your completed questionnaire by 30 September 1993 in the self-addressed envelope provided or fax it to (011) 339-5760 (ATT: Glenda Harrington).

Part A

Please supply the following information about your firm:

Indicate with a tick the industry in which your firm operates. Manufacturing, Financial services, Chemical Retail, Mining, Transport. If other, then please specify: . . .

Part B

Please supply the following information about the implementation of EDI in your firm.

1. Indicate with a tick the implementation stage your firm is currently in: Investigation, Pilot, Internal testing, Live.
2. If "live" was answered in question 1, how long has your firm been trading electronically?
3. Specify the number of firms or organisations in each category with which your firm trades electronically. Suppliers, Customers
   If other, then please specify: . . .
4. Indicate with a tick the class in which your firm falls into with respect to its implementation of EDI.
   - Your firm insisted that its trading partners comply
   - Your firm complied with hub company's request

   (A hub company is the initiator of trade via EDI.)
5. Give a brief reason why your firm decided to implement EDI.
6. Indicate with a tick the platform on which EDI has been, or is intended to be, implemented in your firm. PC's, Mid-range, Mainframe.
   If other, then please specify: . . .
7. Indicate by means of tick, the type of message that is, or is intended to be, transmitted electronically by your firm. Order, Invoice, Payment, Technical specification, Shipping confirmation.
   If other, then please specify: . . .
8. Estimate the number of daily EDI transactions that are, or will be, effected between your firm and its trading partners.
9. Estimate the percentage of all your firm's transactions that are, or will be, transmitted electronically.

Part C

Answer the following set of questions by ticking the response which corresponds to the degree to which each EDI benefit has been realised by your firm. Leave out this section if your firm is still investigating the implementation of EDI, and instead, briefly mention anticipated benefits in Part B, question 5.

1. Inventory holdings have reduced.
   Not realised 1 2 3 4 Extensively realised
2. Just-in-time ordering has been enabled.
   Not realised 1 2 3 4 Extensively realised
3. Customer satisfaction has increased.
   Not realised 1 2 3 4 Extensively realised
4. Supplier responsiveness has improved.
   Not realised 1 2 3 4 Extensively realised
5. A closer relationship with trading partners has resulted.
   Not realised 1 2 3 4 Extensively realised
6. The integrity of data has improved.
   Not realised 1 2 3 4 Extensively realised
7. Payment delays are avoided as a result of fewer mismatch problems.
   Not realised 1 2 3 4* Extensively realised
8. Clerical errors have reduced.
   Not realised 1 2 3 4 Extensively realised
9. Mailing costs have decreased.
   Not realised 1 2 3 4 Extensively realised
10. Forms and stationery expenses have reduced.
    Not realised 1 2 3 4 Extensively realised
11. Better, more timeous and up-to-date information is available for decision making.
    Not realised 1 2 3 4 Extensively realised
12. Staff have been released from routine work and are more optimally utilised.
    Not realised 1 2 3 4 Extensively realised
13. Were any unanticipated benefits realised by your firm after trading had commenced via EDI? If so, give details.

[1] Editor's note: It was not possible to reproduce the questionnaires in their original form and layout – only the content is reproduced.

Table 9.

	PCs	Mid-range	Mainframe
1. Initial costs:			
1.1 Investigation and research			
1.2 If other, then please specify:			
2. Set-up costs:			
2.1 Hardware			
2.2 Communication Equipment			
2.3 EDI Software			
2.4 Modification to existing applications			
2.5 Registration			
2.6 If other, then please specify:			
3. On-going costs:			
3.1 Training			
3.2 Maintenance of hardware and software			
3.3 VAN			
3.4 If other, then please specify:			
4. Notes:			

Part D

How would you rate the success of the implementation of EDI in your firm?

Complete failure 1 2 3 4 Extremely successful

Please supply any further comments you wish concerning the implementation of EDI in your firm.

If you wish, supply the name of your company.

Questionnaire B Cost Analysis

The following questionnaire has been designed to assess the costs of trading electronically in South Africa. The aim is to achieve an estimate of the total cost for various sizes of EDI implementation .

Please supply average cost estimates for each platform and cost category. If it is necessary to clarify any information provided or to bring further information to my attention, please make use of the space provided marked "Notes" at the end of the questionnaire.

Thank you very much for your assistance in this research. Please return your completed questionnaire by 30 September 1993 in the self-addressed envelope provided or fax it to (011) 339-5760 (ATT: Glenda Harrington).

Please supply the information in Table 9 regarding the cost of implementing EDI on various platforms.

Notes for Contributors

The prime purpose of the journal is to publish original research papers in the fields of Computer Science and Information Systems, as well as shorter technical research papers. However, non-refereed review and exploratory articles of interest to the journal's readers will be considered for publication under sections marked as Communications or Viewpoints. While English is the preferred language of the journal, papers in Afrikaans will also be accepted. Typed manuscripts for review should be submitted in triplicate to the editor.

Form of Manuscript

Manuscripts for *review* should be prepared according to the following guidelines.

- Use wide margins and $1\frac{1}{2}$ or double spacing.
- The first page should include:
  - title (as brief as possible);
  - author's initials and surname;
  - author's affiliation and address;
  - an abstract of less than 200 words;
  - an appropriate keyword list;
  - a list of relevant Computing Review Categories.
- Tables and figures should be numbered and titled. Figures should be submitted as original line drawings/printouts, and not photocopies.
- References should be listed at the end of the text in alphabetic order of the (first) author's surname, and should be cited in the text in square brackets [1–3]. References should take the form shown at the end of these notes.

Manuscripts accepted for publication should comply with the above guidelines (except for the spacing requirements), and may be provided in one of the following formats (listed in order of preference):

1. As (a) LaTeX file(s), either on a diskette, or via e-mail/ftp – a LaTeX style file is available from the production editor;
2. As an ASCII file accompanied by a hard-copy showing formatting intentions:
   - Tables and figures should be on separate sheets of paper, clearly numbered on the back and ready for cutting and pasting. Figure titles should appear in the text where the figures are to be placed.
   - Mathematical and other symbols may be either handwritten or typed. Greek letters and unusual symbols should be identified in the margin, if they are not clear in the text.

   Further instructions on how to reduce page charges can be obtained from the production editor.
3. In camera-ready format – a detailed page specification is available from the production editor;
4. In a typed form, suitable for scanning.

Charges

Charges per final page will be levied on papers accepted for publication. They will be scaled to reflect scanning, typesetting, reproduction and other costs. Currently, the minimum rate is R30-00 per final page for LaTeX or camera-ready contributions and the maximum is R120-00 per page for contributions in typed format (charges include VAT).

These charges may be waived upon request of the author and at the discretion of the editor.

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Proofs of accepted papers in categories 2 and 4 above will be sent to the author to ensure that typesetting is correct, and not for addition of new material or major amendments to the text. Corrected proofs should be returned to the production editor within three days.

Note that, in the case of camera-ready submissions, it is the author's responsibility to ensure that such submissions are error-free. However, the editor may recommend minor typesetting changes to be made before publication.

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Letters to the editor are welcomed. They should be signed, and should be limited to less than about 500 words.

Announcements and communications of interest to the readership will be considered for publication in a separate section of the journal. Communications may also reflect minor research contributions. However, such communications will not be refereed and will not be deemed as fully-fledged publications for state subsidy purposes.

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Contributions in this regard will be welcomed. Views and opinions expressed in such reviews should, however, be regarded as those of the reviewer alone.

Advertisement

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References

1. E Ashcroft and Z Manna. 'The translation of 'goto' programs to 'while' programs'. In *Proceedings of IFIP Congress 71*, pp. 250–255, Amsterdam, (1972). North-Holland.
2. C Bohm and G Jacopini. 'Flow diagrams, turing machines and languages with only two formation rules'. *Communications of the ACM*, **9**:366–371, (1966).
3. S Ginsburg. *Mathematical theory of context free languages*. McGraw Hill, New York, 1966.

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